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A Controlled Experiment (Strawman draft) to Test the Impact of Removals of Grey Seals on the Mortality of Southern Gulf Cod

Une expérience contrôlée (Strawman draft) pour vérifier l'impact de l'enlèvement de phoques gris sur la mortalité de la morue du sud du golfe

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TABLE OF CONTENTS

INTRODUCTION 1
GREY SEAL REMOVALS 3
GREY SEAL POPULATION MONITORING 4
DIET MONITORING 4
ECOSYSTEM MODELLING 5
OTHER WORK 5

DISCUSSION 5

REFERENCES 6

TABLES 8

FIGURES 11

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ABSTRACT

In the southern Gulf of St. Lawrence, the weight of evidence suggests that grey seal predation is limiting the recovery of the 4T cod stock and other species such as white hake and skate populations as well. An experiment was outlined to test this hypothesis. Under the proposed experiment clear longterm cod and seal management objectives must be identified, minimum realistic and ecosystem modeling simulations must be completed to identify possible benefits and impacts and then data must be collected to monitor changes in the abundance and dynamics of the seal and cod populations to ensure that the management objectives are attained and to be able to evaluate the effectiveness of the experiment in attaining these objectives.

RÉSUMÉ

Dans le sud du golfe du Saint-Laurent, le poids de la preuve suggère que la prédation des phoques gris limite le rétablissement du stock de morue de 4T ainsi que d'autres espèces comme la merluche blanc et des populations de raies. Une expérience a été décrite pour tester cette hypothèse. En vertu de l'expérience proposée, des objectifs de gestion à long termes clairs pour la morue et les phoques doivent être identifiés. Des simulations réalistes minimales de l'écosystème doivent être complétées pour déterminer les avantages et les incidences possibles. Les données doivent être récoltées pour surveiller les changements dans l'abondance et la dynamique des populations de phoques et de morues afin de s'assurer que les objectifs de gestion sont atteints et d'être en mesure d'évaluer l'efficacité de l'expérience dans la réalisation de ces objectifs.

INTRODUCTION

Several Atlantic cod stocks collapsed in the early 1990s and have shown limited signs of recovery since then. In fact, abundance of cod in the southern Gulf of St. Lawrence continues to decline despite very little fishing mortality. The collapse in cod and other groundfish stocks has been attributed to over-fishing whereas the reasons for the lack of recovery are uncertain and may vary between stocks. Several hypotheses have been proposed including predation by grey seals.

Over the last four decades, populations of harp seals and grey seals have increased substantially. Harp seal numbers have increased from just under 2 million animals in 1970 to almost 7 million in 2009 (Hammill and Stenson 2009a). Among grey seals the increase has been more dramatic, with the Northwest Atlantic population increasing from approximately 13,000 animals in 1960 to roughly 400,000 animals in 2010 (Hammill and Stenson 2011).

In the southern Gulf of St. Lawrence, the weight of evidence suggests that grey seal predation is limiting the recovery of the 4T cod stock and other species such as white hake and skate populations as well. This evidence includes a strong correlation between trends in natural mortality rates (M) among large cod, large hake and skate and grey seal abundance, the high contribution of cod and hake to seal diet, strong overlap between grey seals and overwintering concentrations of cod, and hake, shifts in the distribution of skate and the timing of migration and distribution of hake and cod (Chouinard et al. 2005; Swain and Chouinard 2008; Swain et al. 2009; Harvey et al.2011a ; Hammill 2011 ; Stenson et al. 2011).

If grey seals are to be managed with the ultimate objective of favoring Atlantic cod recovery in the southern Gulf of St. Lawrence (as proposed by FAM), then we propose that this be done within the context of a controlled ecosystem experiment with respect to NAFO division 4T. From a science perspective, whether or not removing grey seals will favour cod recovery needs to be examined within a clearly identified management framework identifying what seal population size and cod stock biomass (and other fish stock) are desired. Associated with this is a need to understand the nature of the interaction between grey seals and cod (i.e. the contribution of grey seal predation to cod mortality M), an evaluation of the number of seals to be removed to attain measurable reductions in M, the expected time to recovery or to attain the management objectives, the operational challenges to removing large numbers of seals, and a research program to measure how the program is meeting its objectives (performance measures).

Seals in Atlantic Canada have been managed under a precautionary approach framework since 2003. This framework is consistent with the Department of Fisheries and Oceans (DFO) PA framework (Fig. 1) (Hammill and Stenson 2009b). In the case of grey seals, the current precautionary management objective is to maintain an 80% probability that the population of grey seals will remain above N70, or 70% of the largest population seen. For grey seals, with a current population estimate of around 400,000 animals, the management objective under the current management plan would be to maintain the population above 280,000 animals. The PA framework developed by DFO identifies a critical reference limit below which removals are to be kept to a minimum. Although all cod stocks in Atlantic Canada are currently below these limits, the PA has not yet been implemented in the management plans for Atlantic cod stocks.

For the development of the following experiment, we outline a proposal to remove grey seals, to evaluate the impact of this removal on their population, improve our information on seal diets and spatial overlap between seals and cod in 4T, monitor changes in M of large cod and improve our estimation of M. Our objective is to observe a reduction in M within 5 years to a level that would lead to increasing cod biomass. The study area is identified as NAFO zone 4T, with the western limit defined by the northeastern tip of Gaspe ie excludes the estuary, but

includes 4Vn, where cod overwinter (Fig. 2). After 5 years, changes in M can be evaluated to determine whether it has been successful in favouring recovery in 4T cod, where it would be expected that the decline in 4T biomass has been reversed. Given the low biomass of the stock, recovery is expected to take some time, even under improved conditions, where recovery is defined as an increase above the critical reference limit with a spawning stock biomass of 80,000 tonnes (Swain et al. 2011). The decision to continue the experiment could be made after evaluating the benefits (recovery among cod) compared to the costs in limiting the grey seal population.

We assume that :

1) the removal of grey seals will lead to reductions in M for large cod, and for recovery to begin, M among large cod must decline to about 0.4 (Swain et al. 2011).

2) the removal of grey seals will reverse the current trend in 4T cod leading to increases in cod biomass.

3) During the experiment, fishing mortality (F) will be kept to a minimum. This will require that the moratorium on directed fishing remains in place.

4) The most likely scenario is scenario 3 (Swain et al. 2011), where grey seals consume 14,550 t of cod aged 5+ in 2005. To reduce M below 0.4, which would favour cod recovery, approximately 78,000 seals (plus annual production) would be removed. A smaller, but undetermined, number would be sufficient if "cod-specialists" could be targetted. For example, if all the consumption of 5+ cod was due to half the seals foraging in the southern Gulf and Cabot Strait, and it was possible to target those seals for removal, then the required removals would be half this number.

5) The removal of grey seals will not lead to serious harm to the grey seal population ie falling below the critical reference level

6) The impacts of seal removals on cod recovery can be examined within a modelling-scenario testing framework (eg ECOPATH with ECOSIM) that will improve our understanding of predator prey impacts, outline scenarios that will contribute to understanding impacts of management actions.

7) The removal of seals will have additional beneficial effects possibly favouring recovery among hake and skate populations in 4T, which will be indicated by declines in M among older individuals in these stocks.

To evaluate the success of any grey seal population reduction in order to facilitate cod recovery, it is necessary to measure the impacts on the cod population, in particular the rate of natural mortality of cod. Estimates of total mortality for fully recruited cod (ages 7 yr and older) can be obtained from the catch at age in the annual bottom-trawl survey. When there is no or very little fishing, this approximates natural mortality. However, several years of data are required to obtain a reliable estimate using this method (e.g., estimates are usually obtained using 5-year blocks of data). Estimates can also be biased by year effects in the survey, so larger time blocks may be required to reliably identify changes in natural mortality. To increase the precision of abundance and M estimates and reduce the likelihood of large year effects from this survey the sampling intensity could be increased by extending the mission by 1 week. At the same time , it would be helpful to have a second complementary method to estimate changes in mortality. Conventional tagging programs can also provide estimates of mortality but

require a substantial fishery to provide tag re-captures, which is not possible at this time due to the severely depleted state of the southern Gulf cod stock. Thus, we propose the following alternative.

An acoustic tagging program could provide annual estimates of mortality. The program would involve tagging cod with acoustic transmitters in the southern Gulf in May (100 cod each year). Lines of hydrophones would be placed along the migration routes to the overwintering grounds in the Cabot Strait, one line across the Cape Breton Trough and a second across the southern slope of the Laurentian Channel. These lines would identify tagged cod leaving the Gulf in the fall and those returning in the spring. Acoustic tags have a 3-year lifespan, so surviving tagged fish could be tracked for 3 years. This program would provide estimates of mortality which could be used to validate estimates from the survey catch at age. These estimates would also have a finer temporal resolution than those from the survey, and could provide information on the seasonal timing of mortality.

Our analyses suggest that there is considerable overlap between grey seals and overwintering aggregations of cod and other groundfish. However, this information comes from a comparison between January groundfish surveys completed between 1995-97 and satellite transmitters deployed between 1995 and 2008. To confirm if this relationship still exists or if there has been a shift in fish distribution a January bottom trawling survey combined with towed or hull-mounted hydrophones and onboard marine-mammal observers would provide new information on winter fish distribution in formation, identify the overwintering locations of the tagged cod; acoustic estimates of cod biomass in overwintering aggregations and presence of marine mammals in the area.

GREY SEAL REMOVALS

Predators likely develop strategies that lead to specialization on particular prey (Bolnick et al. 2003; Tucker et al. 2007, 2009). This complicates efforts to describe an average population diet, but can reduce the numbers of seals that are necessary to remove if such specialists can be targeted. Working papers presented at the meeting indicate that cod forms a more important component of the male diet and that overlap likely occurs in the Cabot Strait area where cod are aggregated and in offshore areas of Miramichi. Other areas where overlap likely occur, as indicated by diet composition are off the west coast of Cape Breton Island, the Magdalen Islands and possibly Gaspe. Although significant numbers of grey seals are found in the Northumberland Strait area, there are few cod there, although targeting grey seals in this area may contribute to reducing M among winter skate and white hake. For targetted removals, particular attention would be paid to hunting in the Miramichi-Gaspe, Magdalen Island, Port Hood to Cape North during summer, then to Magdalen Island, Port Hood to Cape North and Cabot Strait during the fall. These areas tend to have high overlap between cod and grey seals (Harvey et al 2011a,b), particularly in the Cabot Strait area during fall, where consumption of large cod appears to be particularly high (Stenson et al. 2011). Males tend to consume more cod than females (Hammill 2011), and overlap is greatest between large males and large cod (Harvey et al. 2011a,b), but removal of large numbers of males, may allow expansion of females to offshore areas as densities increase, therefore it is recommended that removals occur with a roughly 1:1 sex ratio. Removals would likely occur via contract hunters in offshore areas and through a bounty type system in inshore areas. Both contract hunters and independent sealers would be required to provide a jaw as proof of removal. This will provide information on sex and age structure of removals for monitoring the seal population.

GREY SEAL POPULATION MONITORING

The grey seal population has increased markedly since the 1960s. The Sable Island herd appears to be exhibiting signs of density dependent changes in growth, which appear largely to be mediated through changes in reproductive rates (Bowen et al. 2007), but age-specific reproductive rate data are needed. Some information is available on adult mortality rates (Manske et al 2002; Schwarz and Stobo 2000), but monitoring of these rates in the face of a changing population would be useful.

Live-capture of females on Sable Island during the fall would allow reproductive status to be evaluated using ultrasound. An incisor tooth could be extracted for age-determination.

The removal of seals provides an opportunity to monitor changes in age-specific growth parameters and age-specific reproductive rates through sampling from the harvests in the Gulf/4Vn areas.

Implementation of branding programs on Hay, Pictou, and Henry Islands and on the ice would provide insights into mortality patterns among male and female grey seals in these herds and would allow comparison with rates observed at Sable Island, and would determine if rates differ among adults between the different herds. This will improve our understanding of the dynamics of each herd as well as will contribute to improving information on movements between herds.

DIET MONITORING

The removal of large numbers of animals allows for improved diet sampling, particularly in areas where sampling has been limited (eg Gaspe, Magdalen Islands), and to monitor changes in contribution of cod to the diet where the consumption of cod appears to be high (eg west coast of Cape Breton Island, Cabot Strait, Miramichi). Ideally, this should be combined with trawling efforts to examine local fish abundance in the areas that seals are foraging. Such efforts would improve our understanding of the functional relationship between prey availability and prey selection by seals.

Traditional diet sampling has relied on the identification of hard parts in digestive tracts. Although this provides a direct indication of diet and sampling has covered some areas where there is overlap with cod, and other demersal species (Harvey et al. 2011a,b), there have also been gaps in the diet sampling coverage (eg Magdalen Islands, Cabot Strait-all seasons, western Cape Breton spring, Miramichi males), (Harvey et al, 2011a,b) also showed that some seals may be foraging far enough or long enough offshore that by the time they return to haulout sites, hard part remains may be under-represented in digestive tract samples. Sampling could occur in offshore areas using chartered vessels and in addition to digestive tracts, samples of blubber and muscle will allow application of other approaches eg fatty acid analyses and stable isotope analyses, which in recent years with the development of Bayesian approaches to the application of mixing models will provide further insights into grey seal feeding. These samples may provide insights into foraging offshore, although other challenges using these approaches alone may be encountered.

Harvey et al (2011a) indicated that there is considerable overlap between overwintering aggregations of 4T cod in the Cabot Strait area and that cod may be changing their distribution off the Miramichi area in response to high grey seal abundance and the movements of grey seals, particularly males. (Benoit et al, 2011) suggested that overlap also occurs off the west coast of Cape Breton Island, Gaspe and the Magdalen Islands, though transmitter have not been deployed on seals that haul-out in these areas, Deployment of satellite transmitters on

grey seals in these regions would provide information on foraging overlap between seal foraging trips at sea and cod distribution in these areas.

The removal of large numbers of grey seals, particularly adults are likely to result in immediate changes in grey seal population dynamics. Currently grey seals are assessed on a 3 year rotation. During the timeframe of the experiment, we are suggesting that this be increased to every second year. In addition aerial surveys should be completed in the Gulf to determine the relative distribution of animals between the different regions. Current data dates from the 1980s and mid 1990s (see Table 3 in Benoît et al. 2011) and although there has been little change in the location of colonies, there may have been some shift in the relative importance of the northern/southern/eastern/western Gulf as haulout areas.

The deployment of satellite transmitters on seals provides longitudinal information on seal movements over several months. Detailed information on foraging activity can be obtained when seals are dispersed during summer, or during the fall migrations. This provides insights into the functional relationship between seal foraging activity and the abundance/distribution of prey (Benoit et al. 2011). Combining this information with GPS locations of offshore sampling and information on fish distribution would also contribute more to understanding the functional relationship between prey choise and availability. Currently knowledge of spring movements are limited because the tags are lost during the annual moult.

ECOSYSTEM MODELLING

Removals of large numbers of grey seals are expected to benefit cod, white hake and skate populations in the southern Gulf of St. Lawrence, but may have other unintended effects on the system. Early simulations suggested that grey seal removals will have a beneficial effect on the cod population, but further work is needed to improve model fits and to further explore scenario options.

OTHER WORK

Contaminants: the removal of large numbers of animals provides an opportunity to examine contaminant loads if there are interests in evaluating the potential of grey seals for human or animal consumption.

A cost estimate for a 5 year program is outlined in Table 2.

DISCUSSION

In 1999, a protocol was developed for the scientific evaluation of proposals to cull marine mammals. This protocol was developed under the auspices of the United Nations Environment Program (UNEP 1999). The final report was not vetted by the entire committee, but it does provide some interesting guidelines which are covered in the outline presented above. The data required for the scientific evaluation of a cull proposal for southern Gulf cod are outlined in Tables 1, 1a. UNEP also identified a procedure to evaluate a cull proposal . This procedure would consist of identifying performance measures to determine the efficacy of the cull, building an ecosystem model that includes the minimum number of components necessary to describe the system and then run various scenarios to determine if the methods proposed to monitor the impact of the cull are appropriate. An ECOPATH/ECOSIM model has been developed here to examine the potential impacts of a cull program, but an evaluation of control scenarios and potential benefits is needed.

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TABLES

Table 1a) Based on Table 2 from UNEP protocol using the case of 4T. Data Requirements (Y=Yes, N=NO, TBD=To be determined)

1. Basic Information	
MM population data	Y
Target fish species	Y
Fisheries	Y
Geographical area	Y
2. Cull objectives	
Biological	Y
Operational	TBD
Economic	TBD
3. Ecological Information	
i) Marine Mammal	
Distribution and population	Y
Per capita consumption	Y
Diet	Y
Total consumption	Y
Demographic parameter	Y
ii) Target Fish	
Distribution and migration	Y
Demographic parameters	Y
Current stock assessment	Y
iii) Other predators	
Abundance, diets and consumption,	LIMITED
iv) Other ecosystem components	
Diets and abundance	LIMITED for many invertebrates; Yes for marine fish
4. Fisheries	
Catches & bycatch	Y
Management system	Y
Economic data | Y	
5. Culling Programme	
Duration	5 years, trial period
No. to be killed and method	yes
Measures to estimate no. killed	yes
Target population size	yes
Monitor of mammal population	yes
Monitor effects of cull on target and other species	yes

Table 1b. UNEP Procedure to evaluate Cull proposal from the UNEP protocol

Verify data	4T
Identify species and fisheries to be included in a Minimum Realistic Model (ECOPATH/ECOSIM model used now, but MR could be explored)	Y
Specify quantitative performance measures	Y
Build simulation model (ECOSIM)	Y
Identify alternate scenarios to rest	TBD
Run replicate simulations and estimate performance measure	TBD
Interpret and synthesize results	TBD
Evaluate power of indices to monitor effects of cull	TBD

We have identified additional factors that are also needed in order to meet the requirement for a cod rebuilding plan.

	4T
Precautionary approach for cod	Y
Precautionary approach for seals	Y
Management objective (ie desired cod stock size)	TBD

Table 2. some cost estimates for a science program to favour recovery of 4T cod.

Cod	Year 1	Year 2	Year 3	Year 4	Year 5	total
cod tags 100 x $350	$35.0	$35.0	$35.0	$35.0	$35.0	$175.0
expenses related to tagging	$5.0	$5.0	$5.0	$5.0	$5.0	$25.0
hydrophones + acoustic releases	$150.0					$150.0
deployment + recovery of hydrophones	$8.0	$8.0	$8.0	$8.0	$8.0	$40.0
7 day extension to sept Teleost mission	$85.0	$85.0	$85.0	$85.0	$85.0	$425.0
Winter survey	$240.0	$240.0				
Total cod	$523.0	$373.0	$133.0	$133.0	$133.0	$1 295.0

Seals	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
Diet						
St Paul Island , N=60	24	24	24	24		96
Magdalen Islands (N=100)	15	15	15	15		60
Miramichi (N=60)	9	9	9	9		36
W. Cape Breton (N=60)	9	9	9	9		36
W. Newfoundland	15	15	15	15		60
Gaspe	9	9	9	9		36
contract technical support		60	60	60	60	240
Satellite telemetry PTT & Argos, N=10, Magdalens, C.Breton, NF)	125	125	125	40		415
Student support (N=2)			35	35	35	105
Sable is. Rpd rates	25	25	25	25	25	125
Branding (Hay Is, Pictou, Henry)	15	15	15	15	15	75
Survey	500		500		500	1500
Ecosystem modelling	51	51	51	51	51	255
Contaminants	12.5	12.5	12.5	12.5		50
Travel/meeting	30	30	30	30	30	150
Total Seals	839.5	399.5	934.5	349.5	716	3239
Cod+seals ('000s)	1 362.5	772.5	1 067.5	482.5	849.0	4 534.0

FIGURES

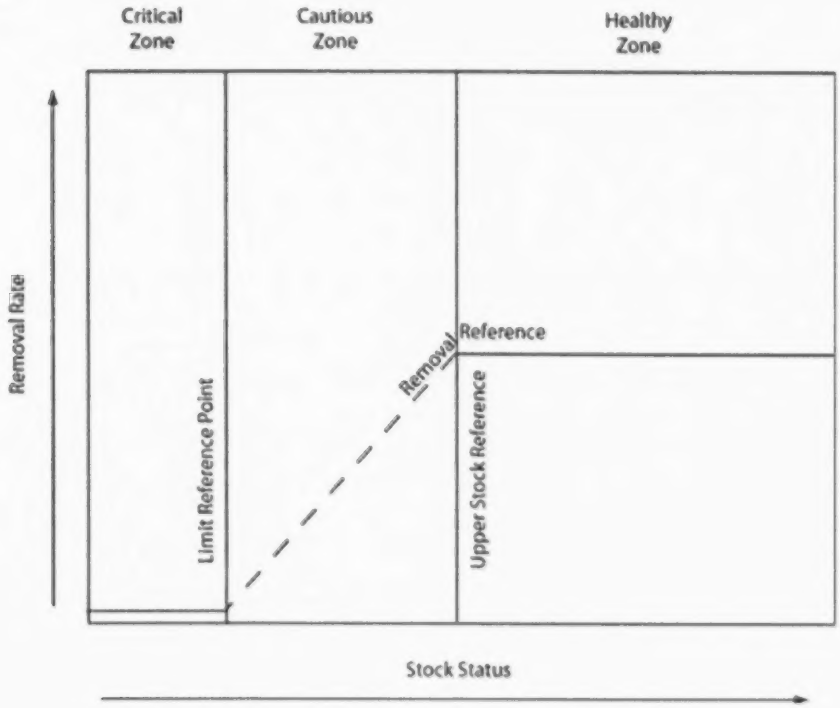

Figure 1. The general Precautionary Approach framework developed by Canada. The stock status zones are created by defining the Limit Reference Point (LRP) at the Critical:Cautious zone boundary, and an Upper Stock Reference Point (USR) at the Cautious:Healthy zone boundary and the Removal Reference for each of the three zones. The three-zoned diagram below shows these different elements. A complete description of the approach can be found at: http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/precaution-back-fiche-eng.htm

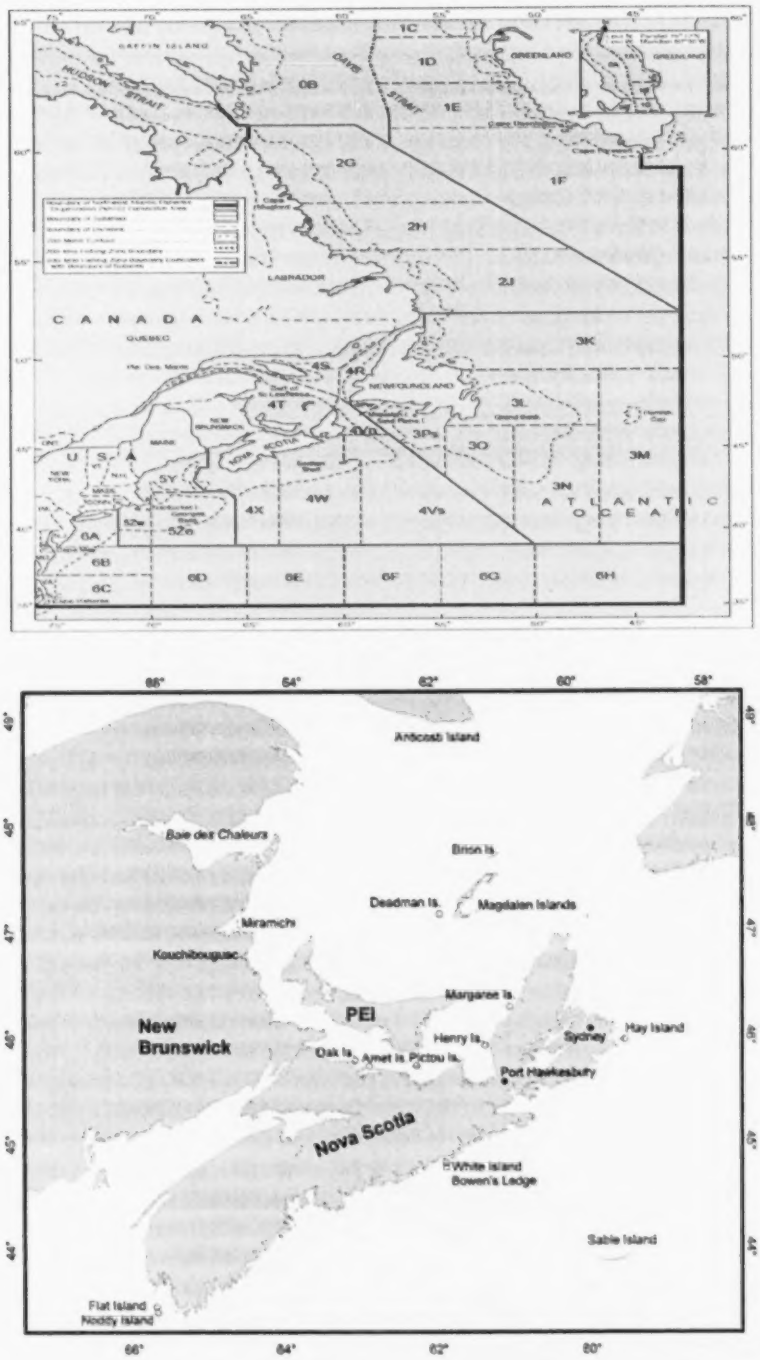

Figure 2. Map showing NAFO fishing zones (top) and southern Gulf of St. Lawrence (bottom). The study area would exclude the estuarine region of 4T.